ARL-TR-7251 ● MAR 2015

US Army Research Laboratory

Development of the Next Generation of Adaptive Interfaces

by Jeffrey T Hansberger

NOTICES

Disclaimers

ARL-TR-7251 ● MAR 2015

US Army Research Laboratory

Development of the Next Generation of Adaptive Interfaces

by Jeffrey T Hansberger
Human Research and Engineering Directorate, ARL

REPORT DOCUMENTATION PAGE						Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
March 2015	DRI	October 2012–October 2014

4. TITLE AND SUBTITLE Development of the Next Generation of Adaptive Interfaces	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Jeffrey T Hansberger	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army Research Laboratory ATTN: RDRL-HRM-DI Aberdeen Proving Ground, MD 21005	**8. PERFORMING ORGANIZATION REPORT NUMBER** ARL-TR-7251
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The objective of this research is to create an interface that is tailored to individual Soldiers' cognitive styles, individual differences, and expertise while at the same time reduces the interface complexity perceived by the Soldier. This interface design will improve upon existing adaptive interfaces by going beyond adaptation to the individual's prior actions and tailoring the interface to how each user perceives, processes, and filters information without the added complexity of current adaptive interfaces. The field of adaptive user interfaces and human-computer interaction will be extended by this tailored interface innovation to investigate Soldier performance benefits of speed, accuracy, understanding, coordination, and the reduction of workload.

15. SUBJECT TERMS

cognitively tailored interface, adaptive interface, individual differences, human-computer interaction, cognitive styles, user interface, UAV

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Jeffrey T Hansberger
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code)
Unclassified	Unclassified	Unclassified	UU	28	256-273-9895

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

1. Objective

The objective of this research study is to design and experiment with an interface that is tailored to individual Soldiers' cognitive styles, individual differences, and expertise while at the same time reduces the interface complexity perceived by the Soldier. This interface design will improve upon existing adaptive interfaces by going beyond adaptation to the individual's prior actions and tailoring the interface to how each user perceives, processes, and filters information without the added complexity of current adaptive interfaces. The field of adaptive user interfaces (UIs) and human-computer interaction will be extended by this tailored interface innovation to investigate Soldier performance benefits of speed, accuracy, understanding, coordination, and the reduction of workload.

2. Introduction/Approach

The tactical and operational environment for the Army is changing with an ever-growing emphasis and need for information. This has created information-overload challenges for the Soldier. Most information and Soldier systems are viewed through a computer interface, but these interfaces are typically ignored or not considered as a vital component in the Soldier system. There is a large amount of diversity in how people perceive, store, and process information. This creates a considerable design challenge, as most interfaces are designed to be one-size-fits-all. Instead of ignoring this diversity, there is great potential in understanding and capitalizing this diversity if the way an interface organizes and presents information could be tailored to each individual and their own cognitive style. Past attempts of adaptive UIs have tried to monitor and/or predict the actions of users and change the interface based on past user actions or predictions of future actions. These interfaces have been largely unsuccessful due to the lack of reliability in user predictions and creating an ever-changing interface that forces the user to constantly learn and understand what the system is doing, especially in dynamic environments like the Army's. This research effort attempts to understand, measure, and design a system to tailor itself according to the information processing strengths and weaknesses of each individual user and Soldier.

The overall approach for this project can be summarized in 3 parts: 1) the redesign of the interface to the unmanned aerial vehicle (UAV) task, 2) development of a new approach to tailor the interface to an individual's cognitive style, and 3) software development to support human performance experimentation for this new approach. The first effort was not initially planned but became a requirement at the initial stages of the project when it was discovered through the task analysis efforts that the current UI was not designed for the current UAV operator's task.

2.1 Interface Redesign

Early versions of UAV systems required manual control of the aircraft, which required pilot training and expertise. As the Army UAV systems became more autonomous, the UAV controls transformed from stick and rudder input devices to "point and click" navigation controls with a mouse and a map. Piloting skills were no longer required, and the task transformed itself from a piloting task to a supervisory control task for UAV operators, where their primary task was to monitor the system for abnormal situations and intervene as necessary. Even though the task itself had transformed and the controls had evolved, the UI and the way information was presented to the operator had not significantly changed. The current UI still presents information to the operators as if they were the UAV pilots from the past using legacy aviation symbology and information. Because of this discovery, the negative feedback that the current UAV UI was receiving from its operators, and the overall poor design of the current UI, I decided to redesign the UAV UI. The redesign was completely independent of the current and legacy systems and was driven specifically by the task and informational requirements of the UAV operator.

2.2 Cognitively Tailored Interface

Once the UI was adequately tailored to the task, the second effort was to continue tailoring the information by customizing it to each individual operator. This approach extends the traditional human systems integration (HSI) approach and takes adaptive interfaces into a different direction than past research. Traditional HSI approaches typically stop tailoring information or the system at the task level mentioned in the previous subsection and do not attempt to consider the cognitive strengths and weaknesses of the individual. One reason for this is the difficulty of considering and designing the diversity and variability among potential users, which has been identified in *Psychology and Neuropsychology*. Ojemann and Schoenfield-McNeill (1999), for example, showed at the neural level that no 2 people's brains store the same information in the same way or in the same place. The individual differences field within psychology has identified dozens of variables that people reliably differ across, including motivation, intelligence, verbal and spatial abilities, and cognitive styles (e.g., Maltby et al. 2007). The challenge of enhancing a Soldier's individual cognitive strengths and compensating for their individual weaknesses should be embraced and not ignored by researchers and system architects.

Adaptive UIs (e.g., Norcio and Stanley 1989) have been one approach to address the user diversity and individual differences design challenge. Adaptive interfaces change their displays and available actions based on the interpreted user's goals and past actions. There has been some success with adaptive interfaces (e.g., Sears and Shneiderman 1994, Findlater and Mcgrenere 2008), but there are considerable costs associated with them as well. One of the primary disadvantages of these systems is that the interface is constantly changing, which impedes learning with repeated use of the system, especially when the adaptive interface is not accurate in its changes (Greenberg and Witten 1985). Adaptive interfaces also place an extra cognitive burden on the user to understand the behaviors and operations of the system in addition to adding complexity to an already complex information environment for the Soldier (Letsu-Dake and Ntuen 2009).

The approach taken with this research was to identify cognitive attributes that were stable over time and provided insight on how each operator individually processed information. Cognitive styles (Riding and Rayner 2007) were selected as this attribute to tailor the information within the UI. Cognitive styles have been found to exist across 2 orthogonal dimensions: a wholistic-analytic and the verbal-imagery dimension. The wholistic-analytic cognitive style continuum describes how an individual organizes and structures information. At the wholistic end of the continuum, there is a tendency and preference to organize and structure information at the global level with an emphasis on the big picture. At the analytic end of the continuum, however, there is a tendency to organize and process information at a detailed level of the individual components. Past research in classroom settings has shown significant performance improvement when the information presented to the students matches their individual cognitive styles (e.g., Riding and Cheema 1991).

Experimenting with the wholistic-analytic cognitive style is meant to be the first of many types of cognitive attributes to which information can be tailored. Other specific attributes that have been identified for future research efforts beyond this project are the imagery-verbal cognitive style and an individual's level of expertise for the task. Future efforts will not only look at the impact of each of these other attributes but also begin to explore the interactions across these attributes. The research approach is summarized in Fig. 1 to show how a repository of promising attributes are tested and then integrated with each other to provide the largest positive impact to the Soldier.

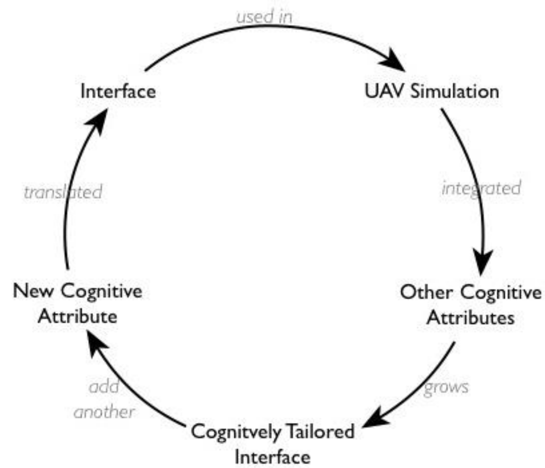


Fig. 1 Research cycle to study and build a repository of cognitive skills and attributes for a cognitively tailored interface

2.3 UAV Experimental Environment

A synthetic task environment (STE) for UAV operations was developed to collect human performance measurements using the cognitively tailored interfaces (CTIs). The STE was based on Wickens and Dixon's (2002) UAV simulation that captures the 3 core components of UAV operations, 1) navigation, 2) visual search for targets, and 3) monitor for system failures, and has enough control to be used for repeated experimentation. The STE has a completely custom UI that can be manipulated to support the different cognitive styles and expertise designs. The STE can simulate multiple short UAV missions and also has human performance data collection capabilities to collect navigation, target search, system monitoring, and situation awareness data. Finally, the STE has the built-in capability to assess the individuals' cognitive style through a short cognitive styles assessment and tailor the interface based on their own specific cognitive style score.

The system tailors the interface to the person's cognitive style by dividing the wholistic-analytic continuum into 3 equal categories to represent 1) wholistic, 2) hybrid, and 3) analytic preferences. A UI was designed for each of the 3 categories, and based on their cognitive style assessment, which is done in real time, the system selects and presents to them the UI that matches their cognitive style. The system and UI do not change, therefore eliminating the problems of a constantly changing interface that past adaptive interfaces have encountered. In order to test and refine these designs before they are used with the UAV STE, another experiment and assessment environment was created to test how well the design facilitates performance for the style of person it was designed for. The results for these 3 project areas are summarized in the following section.

3. Results

3.1 Interface Redesign

A cognitive task and work analysis combined with past research and interviews with UAV operators identified that, fundamentally, controlling the UAV is now primarily a supervisory control task given the high level of automation in the system. The primary requirement for the operator is to monitor the state of the system for emergencies or alerts that need the operator's attention (Wickens and Dixon 2002). The current ground control station UI, however, still presents information as if the UAV operators were the pilots that used the system in the past. Essentially, the current UI is designed for UAV pilots of the past and not the UAV operators of today or tomorrow.

The task analysis confirmed the general negative feedback from interviewed UAV operators related to the current UI for the universal ground control stations (Fig. 2). The task analysis revealed that the interface contained no cohesive design, requiring the operator to figure out the appropriate layout of more than a dozen individual windows and screens. Among this collection of windows, important alerts and warnings can be quickly and easily lost behind other windows.

Fig. 2 An example of a current interface for unmanned aerial vehicle operators

The menu hierarchy for the system is both wide and deep, requiring that the user spend unnecessary time and effort remembering where needed functions and controls exist in the UI (Fig. 3). These significant UI issues, with the lack of support for the system as a supervisory control task, were the motivation to redesign the system based on the current UAV operator's needs and requirements.

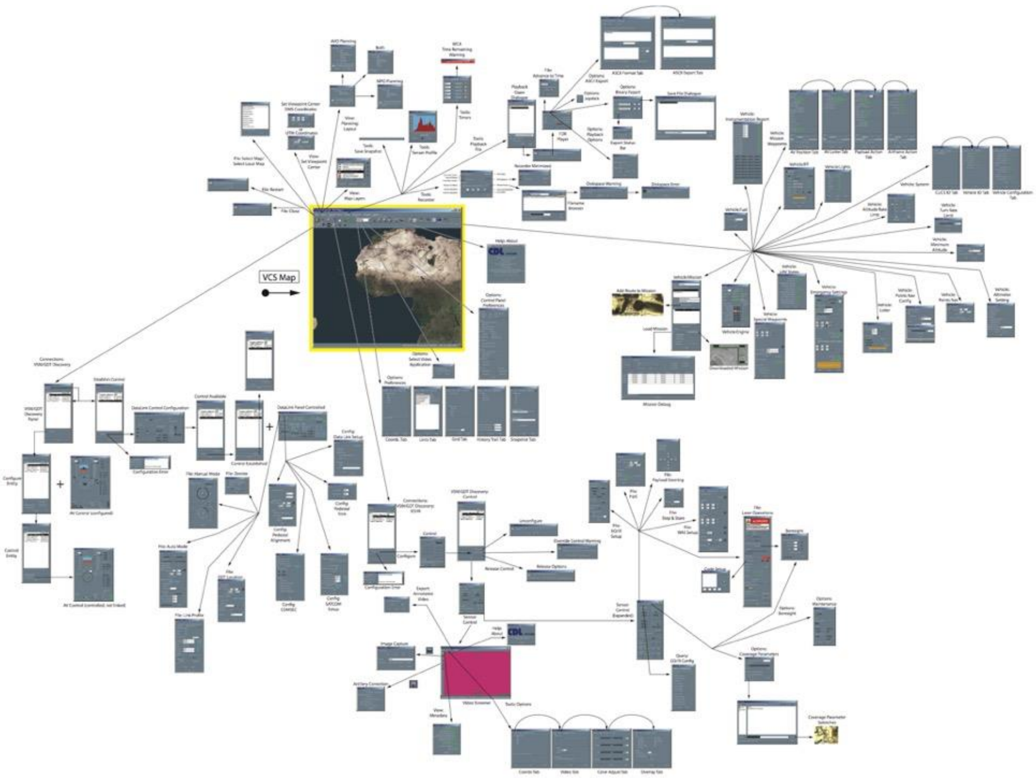


Fig. 3 A portion of the menu hierarchy for a current unmanned aerial vehicle interface

In addition to identifying the 3 core UAV tasks mentioned previously (navigation, visual search for targets, and monitoring the system) and the supervisory control nature of the task, through task analysis and past research we identified 6 critical categories of information UAV operators need to complete their mission (Drury et al. 2006):

- 3-dimensional (3-D) spatial relationships (e.g., UAV location to terrain)
- Weather near the UAV
- Health of the UAV (e.g., warning and alerts)
- Status of the UAV (e.g., landing gear state)
- Operational threats
- Mission-related information

These information categories guided what needed to be visualized and the general organization of that information. Each visualization went through several iterations to produce a dashboard interface design. A dashboard is a visual display that consolidates the most important information on a single screen so the system can be monitored at a glance. These visualizations address the 6 content areas mentioned above and were constructed to take advantage of preattentive processing, which is the early stage of visual perception that rapidly occurs below the level of consciousness. These preattentive visual attributes include organization, color, position, form (orientation, enclosures, proximity), and motion for rapid perception (Ware 2013).

Several data visualization inventions from the leading researchers in the field were used, along with new visual concepts that I invented. Bullet (Few 2006) and sparkline (Tufte 2006) graphs were used to show the status of several aircraft parameters (Fig. 4). These graphs allow a lot of information to be summarized in a small amount of space and monitored quickly by the operator. The sparkline graphs display past performance for each parameter over the last 2 h, which provides a history and context to the current value that is not available in the current or future versions of the ground control stations. This is particularly helpful when one of the parameters reaches a dangerous level. The bullet graphs are a variation of traditional bar graphs, with additional context provided by shading different thresholds within the graph. This provides not only the current value but the relation of that value to important thresholds for that specific parameter.

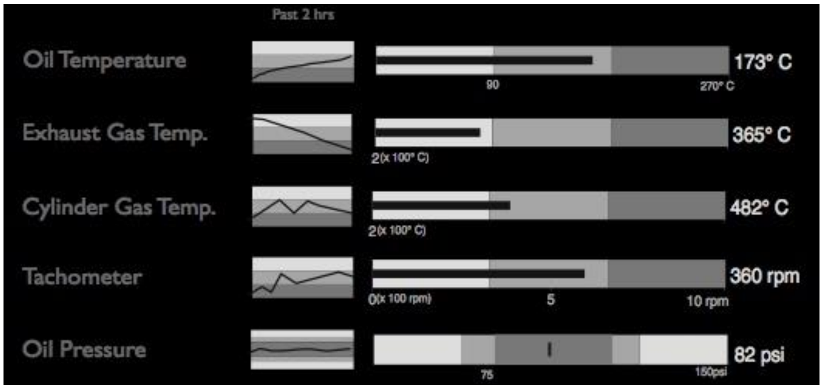


Fig. 4 Sparkline and bullet graphs

Among the new graphs that were created is the flight path graph (FPG). The FPG is a moving cone-shaped graph of relevant information in the immediate path of the UAV (Fig. 5). This integrates 5 of the 6 critical information areas into one graph. If the heading of the UAV changes, the contents in the FPG are dynamically updated to show the operator any new threats or items of interest in the new flight path. The intent for this graph is to show any points or things of interest (e.g., targets, terrain, weather, and operational threats) that are in the current flight path and within a reasonable distance away from the UAV. The FPG also contains information regarding wind speed and direction; it has transformed the UAV operator's task of computing a head or tail wind from an information-seeking task (gathering wind speed, direction, and current UAV heading from 3 different displays) and mental-computation task (placing all that information in short-term memory and comparing the wind direction to heading information) to a simple visual perceptual task of viewing the arrow in relation to the UAV icon on the FPG. There is no comparable graphic in the current or future ground control station interface.

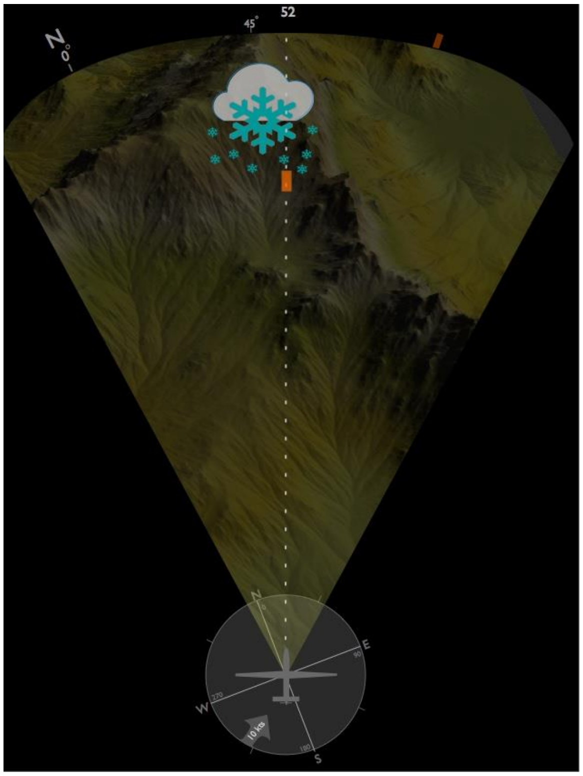


Fig. 5 Flight path graph

Another newly invented graph, the flight path profile graph (FPPG), complements the FPG by displaying much of the same information from a profile perspective. By displaying a moving map from a side perspective with the centerline as the current UAV altitude, we find that the relationship between the UAV and hazardous terrain or obstacles is clear and highlighted (Fig. 6).

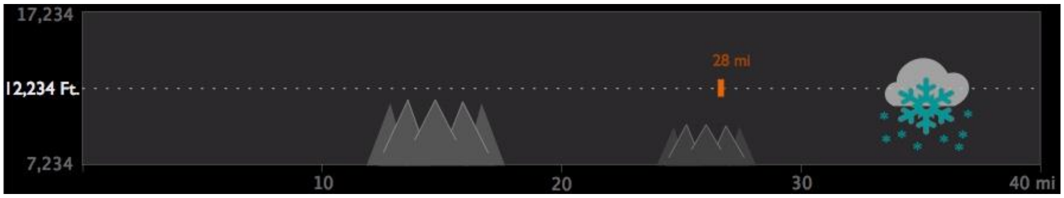
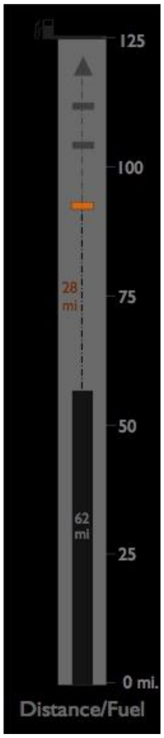


Fig. 6 Flight path profile graph

The final graph is a modified bullet graph to illustrate the spatial relationships between the UAV and 1) takeoff location, 2) multiple planned targets/destinations, and 3) landing site, along with showing the estimated time of arrival to target, distance to empty, fuel status, fuel warning, and where along the planned flight path fuel may reach empty (Fig. 7). The flight path is transformed and shown along a linear distance path where the bottom of the graph represents the origin point where the UAV took off. The bar itself represents the distance flown, and the various bars represent planned targets/destinations showing the relative distance between each other and to the UAV itself. The triangle represents the landing area, which may or may not be the same as the takeoff location. If fuel is calculated to run out at any point within the flight plan, a red fuel icon is displayed and moves into the position along the flight plan where fuel would expire (Fig. 8). Any changes in the flight plan will trigger the fuel alert to be recalculated and displayed.



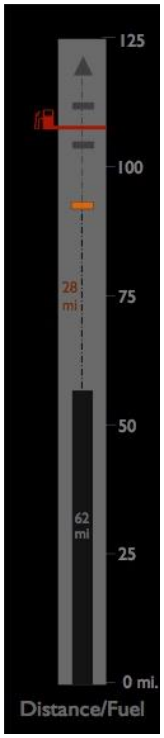


Fig. 7 Distance/fuel graph **Fig. 8 Distance/fuel graph with fuel warning**

3.2 Cognitively Tailored Interface

The first of several planned cognitive skills and styles (Fig. 1) was created using the wholistic-analytic cognitive style dimension. The wholistic-analytic cognitive style continuum describes how an individual organizes and structures information. The wholistic-analytic scores were divided into 3 equal score ranges to create 3 categories of users and matching interfaces: 1) wholisitic, 2) hybrid, and 3) analytic.

The wholistic interface emphasizes information at a global level and displays more details only when an alert is triggered or on demand by the user. The wholistic interface emphasizes the FPG because of its ability to generate the "big picture" of the current flight path (Fig. 9). Additional details are hidden until necessary for the aircraft status, which shows the sparkline graphs across all flight parameters with the exact value and its corresponding bullet graph hidden. A simple check mark is provided as a high-level indicator that each of those system parameters is within normal working ranges. The details are only shown to the user when that parameter reaches a dangerous level in order to further diagnose the issue or if the user wants to inspect it by manually clicking on that parameter.

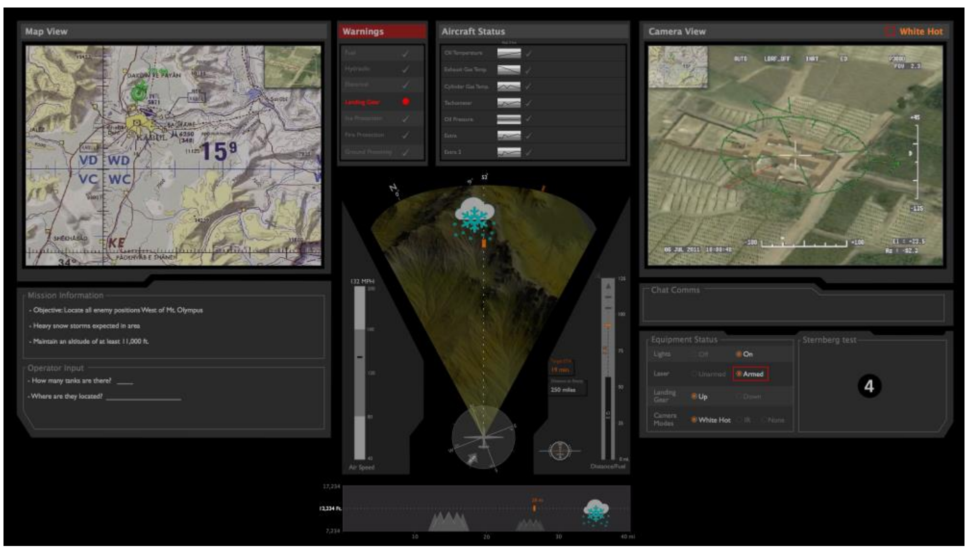


Fig. 9 The wholistic cognitively tailored interface version

The analytic interface, on the other hand, places the information emphasis on lower-level details. Figure 10 shows the analytic version with the bullet graphs and exact aircraft status values displayed instead of the more generic check mark found in the wholistic version. The FPG has been replaced by the FPPG based on its ability to better support the detailed table information found under it. The table provides details related to the threats, terrain, targets, and weather shown in the FPPG. Additional details are provided for the fuel status in the form of 2 additional bullet graphs.

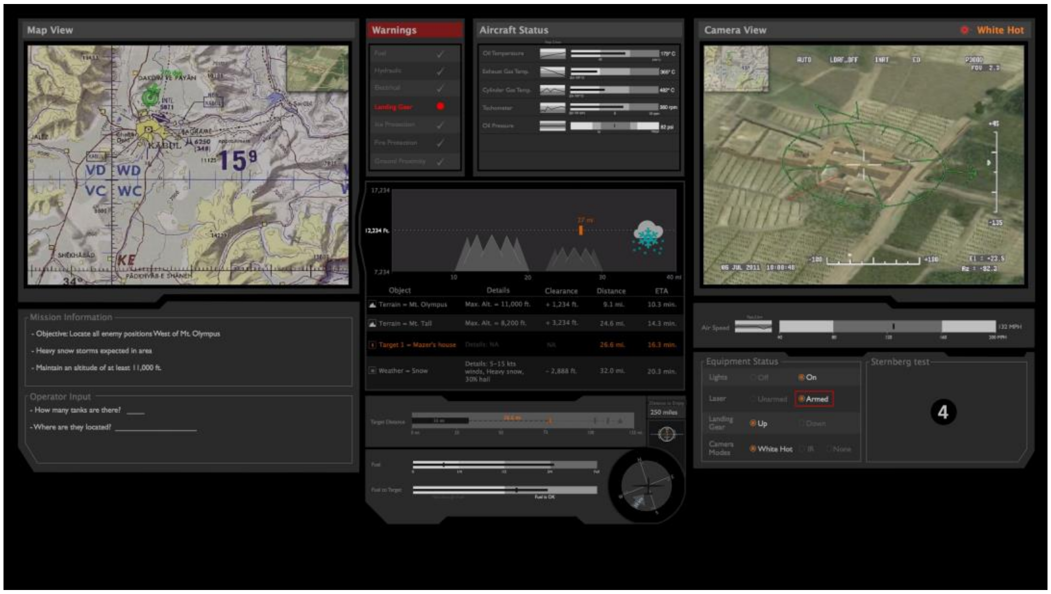


Fig. 10 The analytic cognitively tailored interface version

The hybrid interface attempts to tailor the information to those individuals that fall between the 2 wholistic-analytic extremes by providing both a high-level overview and the details within the analytic interface. The overview is provided by the inclusion of both the FPG and FPPG and only gives the detail views of aircraft status when there is an alert (Fig. 11). Details are provided with the inclusion of the table that complements the FPPG data.

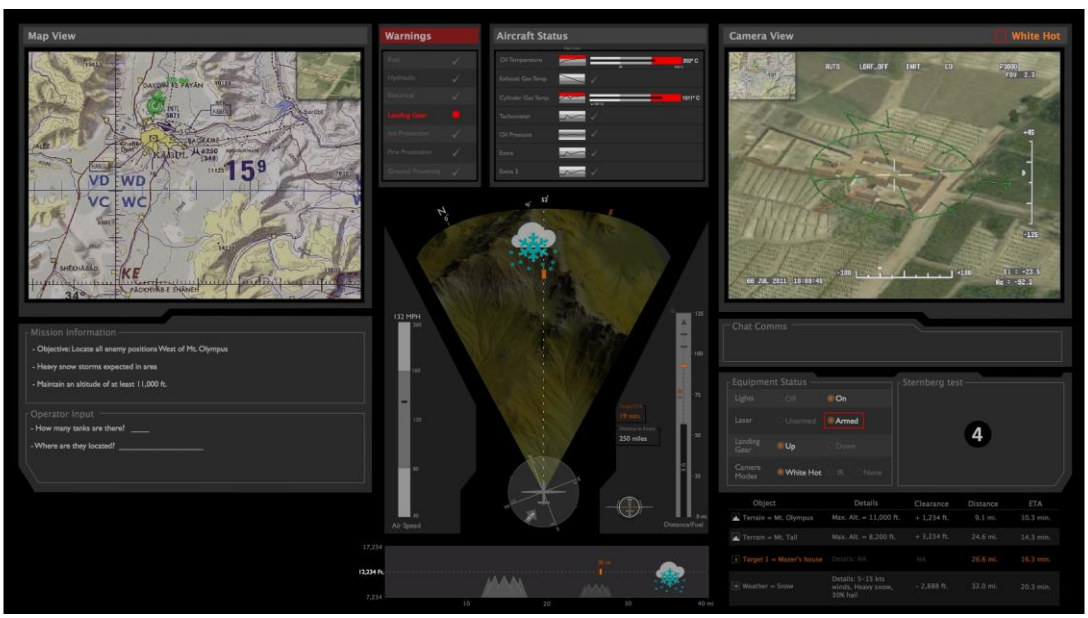


Fig. 11 The hybrid cognitively tailored interface version

3.2.1 Goodness-of-Fit Experiment

The creation of the CTIs involves 3 primary steps: 1) tailoring information based on the targeted cognitive skill/attribute, 2) testing the design, and 3) refining the information design. A testing environment was created to test the designed CTI based on user performance and user preference. The purpose of this type of experiment is to refine and validate the design generated, which may take several iterations to appropriately match how the information is presented through the UI with that cognitive attribute of the individual.

3.2.1.1 Goodness-of-Fit-Study Overview

The study presented the participants with 3 types of interface designs to investigate how their preference varies between the interface designs and their measured cognitive style along the wholistic and analytic dimension. The participants were presented with still images of the interface and asked to extract specific information from it to gauge their preference among the 3 interface types.

Seventeen college student volunteers from the University of Alabama at Huntsville were recruited. All responses were electronically collected via mouse and keyboard inputs. The Extended Cognitive Styles Analysis–Wholistic Analytic test (ECSA-WA) (Peterson and Deary 2006) is a cognitive task that compares how long the participant takes to judge the similarity of 2 shapes (wholistic task) with how long the participant takes to judge whether a particular shape is embedded in a more complex shape (analytic task). Participants were encouraged to perform the test at their own pace, and the stimuli remain on the computer screen until answered.

3.2.1.2 Procedure

The interface chosen for the experiment is one for operating UAVs. The experiment included a practice session. The hypothesis is that the interface that matches the person's cognitive style will be preferred and used more often by the user.

Participants went through a short eye-tracking calibration procedure (5 min) where they looked at different points of the computer screen for a few seconds each. They then completed the ECSA-WA on a computer. They were introduced to each interface with instructions on how to read the instruments. For each of the 3 interfaces presented, the participants were asked 5 questions to provide practice reading the interface. All 3 interfaces were displayed on a single screen, and the participant was asked 20 questions about information represented in the interfaces. The order and placement of the 3 interfaces were randomly presented for each question. All the interfaces displayed the same data, just in different ways. Eye-tracking data was used to detect consistent patterns of use. This session was followed by a short interview session that asked their subjective preferences and feedback on how they used the interfaces.

3.2.1.3 Results

The results from the ECSA classified the majority of the participants as having an analytic cognitive style (n = 7, 50%), followed by a hybrid cognitive style (n = 5, 36%), with the least amount of participants classified as having a wholistic cognitive style (n = 2, 14%). The response accuracy to the ECSA was very high (96%). The student volunteers were all engineering students, which explains the high rate of analytic styles and low rate of wholistic styles among this sample. Accuracy in the CTI survey was 90% for both the performance and preference sections. Participants spent an average of 14.15 s (*SD* = 12.71 s) on each of the performance questions, and 10.57 s (*SD* = 5.86 s) on each of the preference section questions.

Participants completed a self-report questionnaire at the end of the experiment to report which interface they preferred. The questionnaire revealed that 71% of the participants preferred the interface that matched their cognitive style scores. Eye-tracking data gave additional insight into their preferences by tracking where their attention was allocated to the most when all 3 interfaces were presented. Among the 15 participants that had usable eye-tracking data (e.g., Fig. 12), 50% of them spent the most time on their matching interface. These results suggest that the design used for each of the 3 wholistic-analytic cognitive styles matched their individual cognitive styles to some degree.

The feedback and performance on the questions provided valuable insight that led to additional tailoring of the data visualizations to each of their respective cognitive style type. These changes have been implemented into the latest version of the interfaces for future testing and evaluation. Additionally, future experiments will address the unequal distribution of cognitive styles represented in the experimental sample.

Fig. 12 An example heat map showing the distribution of eye gazes for one participant across the 3 cognitively tailored interface designs as they retrieve information to answer a question

3.3 UAV Experimental Environment

The UAV experimental environment will be used to measure the effect of the wholistic-analytic CTI in addition to future cognitive styles and attributes to be added to the system. The design and development of the UAV experimental environment proved to be the most ambitious component of the research. The complete experimental environment is still under development. The experimental environment consists of 4 components:

- Cognitive style assessment tool
- Customizable UI with unique data visualizations
- Customizable UAV flight simulator
- Embedded human performance measures for UAV operations

The cognitive style assessment tool consists of both the ECSA-WA test and the Verbal-Imagery Cognitive Style test (Peterson et al. 2005). Both tests have been implemented into the experimental environment so the scoring is automated and immediately available for the system to select the matching interface design based on that individual's cognitive style/s. Additional testing mechanisms for other cognitive skills and levels of domain expertise can be added to the system to continue expanding its scope.

The customizable UI was critical to the experimental environment in order to present the user with different data visualizations and interface configurations based on their individual cognitive attributes. The flexibility needed within the UI prevented the use of any commercial off-the-shelf products and drove the development to a completely custom system. The benefit of this allows for complete control over the UI configuration and few limitations on the type of data visualizations that can be invented and experimented with.

The UAV simulation allows the experimenter to customize a 50- to 70-min mission consisting of 10 legs with command targets at the end of each leg and based off of a similar STE developed by Wickens and Dixon (2002). Each leg is approximately 5–8 min long and covers about 10–12 km in distance. An Xbox controller is used to manipulate the aircraft and camera view. Within the simulation, a map view and a camera view are presented (Figs. 9–11). The command target is located at the end of each mission and requires the operator to loiter around it once it is detected and respond to questions regarding the command target.

As mentioned previously, the task is structured around the 3 critical and fundamental tasks of the UAV operator: 1) navigation, 2) target detection, and 3) monitoring for system failures. Navigation is done by entering destination coordinates and/or manually directing the UAV. Target detection is supported by introducing targets of opportunity (TOO) into the mission legs. A TOO is a square bunker in 3 sizes with 1–3 tanks and/or helicopters surrounding it. There is one TOO per mission leg, which is randomly located in the middle 60% of the screen. The system records any detections and reaction times for detections. The final task of system monitoring is done by simulating system failures and alerts. Each system failure lasts for 30 s and then auto-resets if not detected. There are 8 system failures for the mission, so not every leg has one and no leg has more than one. The number of correct detections and reaction time of detection is automatically recorded by the system.

In addition to these performance measures, situation awareness is assessed by pausing the simulation at 3 random times within the mission. The information on the screen is hidden during these situation awareness segments, and 4 questions about the state of the system are presented to the user to answer. Their accuracy and response time is recorded. Workload will also be manipulated creating different workload conditions.

4. Conclusions

This research project has attempted to expand the current human system design approach from designing for the masses to designing for the individual. The value placed on information will only increase in the future. The better able we are to tailor information to the individual needs and requirements of both the user's task and the individual attributes of the user, the more power and knowledge we can provide them. This still remains largely an unexplored area for considerable future research.

In attempting to create a CTI for the UAV domain, new ways to visualize information to the UAV operators were invented that are based primarily on the nature of the task and what we know about the psychology of perception. A CTI was designed and implemented with preliminary testing conducted. Additionally, a research paradigm to investigate a growing repository of cognitive attributes and skills was created along with the tools, measures, and experimental environments needed to investigate these issues further.

Future efforts will continue with the experimentation paradigm developed in this project (Fig. 1) with the completed UAV experimental environment while also working with the unmanned aerial systems operators, developers, and community to transition the designs and technology that can improve performance for UAV operators.

5. Transitions

Hansberger JT. Cognition in military wireless devices. Invited Panel conducted at the IEEE Military Communications Conference, Orlando, FL; c2012

Hansberger JT. Keystroke level modeling for UAV ground control stations. MANPRINT Workshop, Alexandria, VA; c2012.

Hansberger JT. UAV Dashboard Visualizations. 6th International Conference on Human Factors and Ergonomics. Las Vegas, NV; c2015.

Hansberger JT. Cognitive Tools for Target Detection. Indo-US Science and Technology Collaboration Project; (under review).

Influence on the 2015 DSI topic, Multi-Dimensional, Individually Adapted Performance Augmentation.

6. References

Drury JL, Riek L, Rackliffe N. A decomposition of UAV-related situation awareness. Proceedings of Human-Robot Interaction Conference, Salt Lake City, UT; c2006.

Few S. Information dashboard design: the effective visual communication of data. New York (NY): O'Reilly Media; 2006.

Findlater L, Mcgrenere J. Impact of screen size on performance, awareness, and user satisfaction with adaptive graphical user interfaces. Proceedings of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems; c2008. p 1247–1256.

Greenberg S, Witten IH. Adaptive personalized interfaces: a question of viability. Behavior & Information Technology. 1985;4(1):31–45.

Letsu-Dake E, Ntuen CA. A conceptual model for designing adaptive human-computer interfaces using the living systems theory. Systems Research and Behavioral Science System Research. 2009;2:15–27.

Maltby J, Day L, Macaskill A. Personality, individual differences and intelligence. London (UK): Pearson Education; 2007.

Norcio AF, Stanley J. Adaptive human-computer interfaces: a literature survey and perspective. IEEE Transactions on Systems, Man, and Cybernetics. 1989;19(2):399–408.

Ojemann G, Schoenfield-McNeill J. Activity of neurons in human temporal cortex during identification and memory for names and words. Journal of Neuroscience. 1999;109:5674–5682

Peterson ER, Deary IJ. Examining wholistic-analytic style using preferences in early information processing. Personality and Individual Differences. 2006;41:3–14.

Peterson ER, Deary IJ, Austin EI. A new measure of verbal-imagery cognitive style: VICS. Personality and Individual Differences. 2005;38:1269–1281.

Riding R, Cheema I. Cognitive styles-an overview and integration. Educational Psychology. 1991;11(3-4):193–215.

Riding R, Rayner S. Cognitive styles and learning strategies: understanding style differences in learning and behavior. New York (NY): David Fulton Publishers; 2007.

Sears A, Shneiderman B. Split menus: effectively using selection frequency to organize menus. ACM Transactions on Computer–Human Interaction. 1994;1(1):27–51.

Tufte E. Beautiful evidence. Cheshire (CT): Graphics Press; 2006. ISBN 0-9613921-7-7.

Ware C. Information visualization: perception for design. Boston (MA): Elsevier and Morgan Kaufmann; 2013.

Wickens C, Dixon S. Workload demands of remotely piloted vehicle supervision and control: single vehicle performance; September 2002. Report No.: AHFD-02-10/MAD-02-1.

1 (PDF) DEFENSE TECHNICAL
INFORMATION CTR
DTIC OCA

2 (PDF) DIRECTOR
US ARMY RESEARCH LAB
RDRL CIO LL
IMAL HRA MAIL & RECORDS MGMT

1 (PDF) GOVT PRINTG OFC
A MALHOTRA

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM D
T DAVIS
BLDG 5400 RM C242
REDSTONE ARSENAL AL 35898-7290

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRS EA DR V J RICE
BLDG 4011 RM 217
1750 GREELEY RD
FORT SAM HOUSTON TX 78234-5002

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM DG J RUBINSTEIN
BLDG 333
PICATINNY ARSENAL NJ 07806-5000

1 (PDF) ARMY RSCH LABORATORY – HRED
ARMC FIELD ELEMENT
RDRL HRM CH C BURNS
THIRD AVE BLDG 1467B RM 336
FORT KNOX KY 40121

1 (PDF) ARMY RSCH LABORATORY – HRED
AWC FIELD ELEMENT
RDRL HRM DJ D DURBIN
BLDG 4506 (DCD) RM 107
FORT RUCKER AL 36362-5000

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM CK J REINHART
10125 KINGMAN RD BLDG 317
FORT BELVOIR VA 22060-5828

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM AY M BARNES
2520 HEALY AVE
STE 1172 BLDG 51005
FORT HUACHUCA AZ 85613-7069

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM AP D UNGVARSKY
POPE HALL BLDG 470
BCBL 806 HARRISON DR
FORT LEAVENWORTH KS 66027-2302

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM AT J CHEN
12423 RESEARCH PKWY
ORLANDO FL 32826-3276

1 (PDF) ARMY RSCH LAB – HRED
HUMAN SYSTEMS
INTEGRATION ENGR
TACOM FIELD ELEMENT
RDRL HRM CU P MUNYA
6501 E 11 MILE RD
MS 284 BLDG 200A
WARREN MI 48397-5000

1 (PDF) ARMY RSCH LABORATORY – HRED
FIRES CTR OF EXCELLENCE
FIELD ELEMENT
RDRL HRM AF C HERNANDEZ
3040 NW AUSTIN RD RM 221
FORT SILL OK 73503-9043

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM AV W CULBERTSON
91012 STATION AVE
FORT HOOD TX 76544-5073

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM DE A MARES
1733 PLEASONTON RD BOX 3
FORT BLISS TX 79916-6816

8 (PDF) ARMY RSCH LABORATORY – HRED
SIMULATION & TRAINING
TECHNOLOGY CENTER
RDRL HRT COL G LAASE
RDRL HRT I MARTINEZ
RDRL HRT T R SOTTILARE
RDRL HRT B N FINKELSTEIN
RDRL HRT G A RODRIGUEZ
RDRL HRT I J HART
RDRL HRT M C METEVIER
RDRL HRT S B PETTIT
12423 RESEARCH PARKWAY
ORLANDO FL 32826

1 (PDF) ARMY RSCH LABORATORY – HRED
HQ USASOC
RDRL HRM CN R SPENCER
BLDG E2929 DESERT STORM DRIVE
FORT BRAGG NC 28310

1 ARMY G1
(PDF) DAPE MR B KNAPP
300 ARMY PENTAGON RM 2C489
WASHINGTON DC 20310-0300

ABERDEEN PROVING GROUND

12 DIR USARL
(PDF) RDRL HR
L ALLENDER
P FRANASZCZUK
K MCDOWELL
RDRL HRM
P SAVAGE-KNEPSHIELD
RDRL HRM AL
C PAULILLO
RDRL HRM B
J GRYNOVICKI
RDRL HRM C
L GARRETT
RDRL HRM DI
J HANSBERGER
RDRL HRS
J LOCKETT
RDRL HRS B
M LAFIANDRA
RDRL HRS D
A SCHARINE
RDRL HRS E
D HEADLEY

INTENTIONALLY LEFT BLANK.